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SOIL FAUNA STUDIES IN A BEECH FOREST II. COMPARATIVE STUDIES ON SOIL INVERTEBRATES IN A FOREST, FOREST MARGIN AND A CLEAR-CUT AREA IN HUNGARY

ZS. BOKOR

Department of Ecology, Kossuth Lajos University, H-4010 Debrecen P.O. B. 14. Hungary

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Abstract

In this paper we examined the soil fauna of a beechwood (Bükk Mts.) and the adjacent clear-cut area in northern Hungary during a four-year period from the third year after deforestation. In this research pitfall traps (Barber traps), as well as litter and soil samples were used. Investigations covered the following broad taxa of the soil invertebrate fauna: *Carabidae, Staphylinidae, Arachnoidea, Diplopoda, Chilopoda, Oniscoidea.*

We endeavoured to explore the effects of clear-cutting on the soil fauna, i.e. how it influences population densities, diversity, and the structure of the food chain.

In the clear-cut and the margin the relative abundance of predatory groups (*Arachnoidea, Chilopoda, Formicidae, Carabidae*) was found two times larger than in the forest interior. No significant difference was pointed out in the occurrence of litter decomposers (*Diplopoda, Isopoda*) between the forest and the clear-cut area.

As a result of clear-cutting the abundance of faeces decomposers (*Scarabidae*) declined.

Key words: clear-cut, soil invertebrates, beech forest, soil fauna.

Introduction

In silvicultural practice, mature forest stands are harvested by logging (partial cutting), provided climatic conditions, field morphology and the species' characteristics allow. Where they do not, clear-cutting is employed (DANSZKY, 1973).

Shortly after deforestation the species composition of the soil arthropod fauna will probably alter due to changes in habitat conditions; later it will be rearranged along with secondary succession of vegetation following disturbance. Removal of tree trunks and stumps makes the ground virtually ploughed; the litter and the top soil layers, together with their organisms, are severely disturbed. Secondary succession following deforestation can be traced by consecutive, year-by-year sampling and comparison of clear-cut spots with intact forest stands.

This article examines 17 taxa of the soil arthropod fauna on the "Rejtek" research area. Beyond the number of individuals, abundance and frequency figures relative to the entire soil fauna were considered. Changes in the relative importance of different food-getting strategies and assemblages were compared among the forest, the transitional zone and the clear-cut.

The abundance and diversity, as well as immigration activity of *Carabidae* and *Staphylinidae* were studied by SUSTEK (1984), SZABÓ (1985), IZSVÁK (1984) and HUHTA (1976), comparing forest and clear-cuts. KLEINER (1977) dealt with the same taxa, contrasting populations in a forest and the neighbouring pasture.

WINTER (1987) and SHAEFER (1980) analyzed the density and diversity patterns

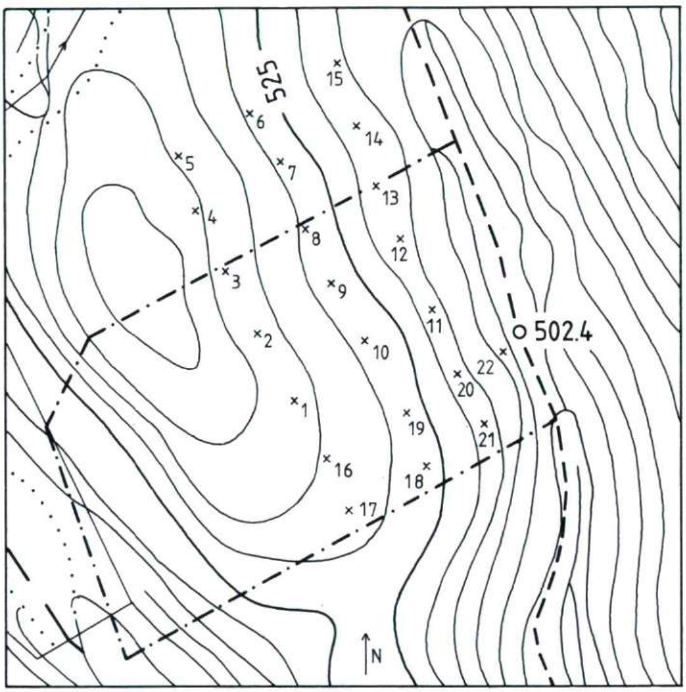

Fig. 1. Location of the sampling area North Hungarian Central Range, Bükk (mountain) Rejtek Projekt

of *Carabidae, Aranei, Opiliones,* and *Pseudoscorpio* after burning of a coniferous wood. The effects of clear-cutting on two of the latter taxa, *Aranei* and *Pseudoscorpionidae* were treated by HUHTA (1976), also including chilopods and staphylinids. In microscopic litter decomposers, different activities were found by SEASTEDT and CROSSLEY (1981), ABBOTT and CROSSLEY (1982) and BLAIR and CROSSLEY (1988). Macrosized litter eaters (*Diplopoda, Oniscoidea*) were studied by SZABÓ (1985) and IZSVÁK (1984), comparing beechwood with clear-cut.

Study area

The 16 ha area is located in Bükk Mts. (part of the Central Hungarian Range), at an altitude of 500 m, with three well-contoured subdivisions: the central plateau, the north-eastern slope (inclination 10-20^0), and the south-western slope (15-20^0). For more details on the area see JAKUCS (1987).

Until the winter of 1980, there had been a 100-120 year old beechwood (*Melico-Fagetum* association) covering the area; in January, 1981, a 4.3 ha spot was deforested by clear-cutting to provide subject for scientific research.

Our studies on the soil fauna started in 1983, the third year after deforestation, with sampling sites positioned on the NE slope, both in clear-cut and the unbroken forest stand.

Sampling method and data analysis

Covered Barber traps, which are a widespread means of sampling soil meso- and microarthropods (LOKSA, 1966; MÜLLER, 1965), were used, while to collect litter and soil samples a 25 by 25 cm square metal frame was applied

The arrangement of sampling sites was determined considerably by topographic and vegetational heterogeneity of the area. Three plots were marked in the forest, the forest edge and the clearcut, respectively. According to our preliminary studies (BOKOR and TÓTHMÉRÉSZ, 1991) these habitats differ significantly and comparisons are well-established by successive sampling. For the four years of the study (1983, 1984, 1985, 1987) permanent traps were set up: there were 6 in the forest, 3 in the margin and 13 in the clearcut (for the arrangement of traps, see Fig. 1.). Samples were taken in every 4 weeks from April to October. From the substancial invertebrate captures the following arthropod taxa were recorded:

Coleoptera: Carabidae, Staphylinidae, Scarabidae

Arachnoidea: Aranei, Opiliones, Pseudoscorpionidae

Chilopoda: Lithobiomorpha, Scendyliomorpha, Geophilimorpha

Diplopoda: Juliformia, Glomeridae, Polydesmidae, Polyxenidae

Isopoda: Oniscoidea

Hymenoptera: Formicidae

Symphyla, Diplura

Summing up the number of individuals per habitat, the frequency of the single taxa relative to the total number of individuals (RFT) was calculated, as well as the relative frequencies in each habitat compared to the same base (RFH). RTF and RFH values are shown in Figs. 3, 4, 5, 6.

Results

The number of specimens altogether captured on the soil surface was 7507 in 1983, 9150 in 1984, 3651 in 1985, and 6192 in 1987 (Table 1.).

Predatory groups are seen to be dominant (40-50%): these are *Carabidae, Staphylinidae, Arachnoidea, Chilopoda, Formicidae*; litter and faeces decomposers (*Isopoda, Diplopoda, Scarabidae*) were represented only with 20-30% and 10-20%, respectively. These figures indicate that less conspicuous, less mobile though abundant arthropod taxa, food for carnivores are under-represented in traps. Individuals of *Polyxenidae, Scendylidae, Geophylidae, Symphyla* and *Diplura* were found almost exclusively in soil samples (Table 2.).

Coleoptera, over and above its remarkable species richness, is considered the most important arthropod taxon in soil (DUNGER, 1983)). RFT values for the subject families (*Carabidae, Staphylinidae* and *Scarabidae*), jointly and severally, reached their maximum in the forest, decreasing gradually towards the clear-cut area (Fig. 3.). In the greatest proportion *Scarabidae* spp were sampled, preceding *Carabidae* and the least abundant *Staphylinidae*. The distribution of total *Coleoptera* counts among the three habitats indicates a strong preference for the forest vs. the clearcut or the transitional zone. In comparison with the rest of soil arthropod fauna, percentage of *Carabidae* and *Staphylinidae* appears fairly uniform, whereas that of *Scarabidae* is rather more uneven (Fig. 3.).

The proportion of total *Staphylinidae* counts in the forest increases substancially from the third year after deforestation, meanwhile declines rapidly in the clearcutr and the intermediate zone. Their relative frequency compared to the whole soil fauna (RFT), however, is scarcely higher in the wood than on the other spots.

RFT values for *Scarabidae* decrease from the forest outwards in accordance with the changing division of the global number of mindividuals. Fluctuations in the number of specimens are concordant in the three habitats reflecting the special sensitivity of this group to changes in climatic conditions (particularly rainfall and temperature).

From *Arachnoidea*, the relative abundance of *Aranei* and *Opiliones* is around 10-15% in the clearcut and the forest edge, while in the forest it remains below 10%.

These important carnivorous taxa exhibit year-by-year alternation in relative abundance (Fig. 4.). The density of *Aranei* decreases from the clearcut towards the forest, while the number of individuals is the best-balanced in the forest margin.

Regarding *Opiliones*, habitats differ markedly according to the distribution of total counts: on the average, 40% occurs in the clearcut and the forest edge, albeit in the wood only 10-20% is present.

Pseudoscorpionidae were captured in extremely small amounts; its relative abundance stays below 1% everywhere, distributed almost uniformly among the habitats.

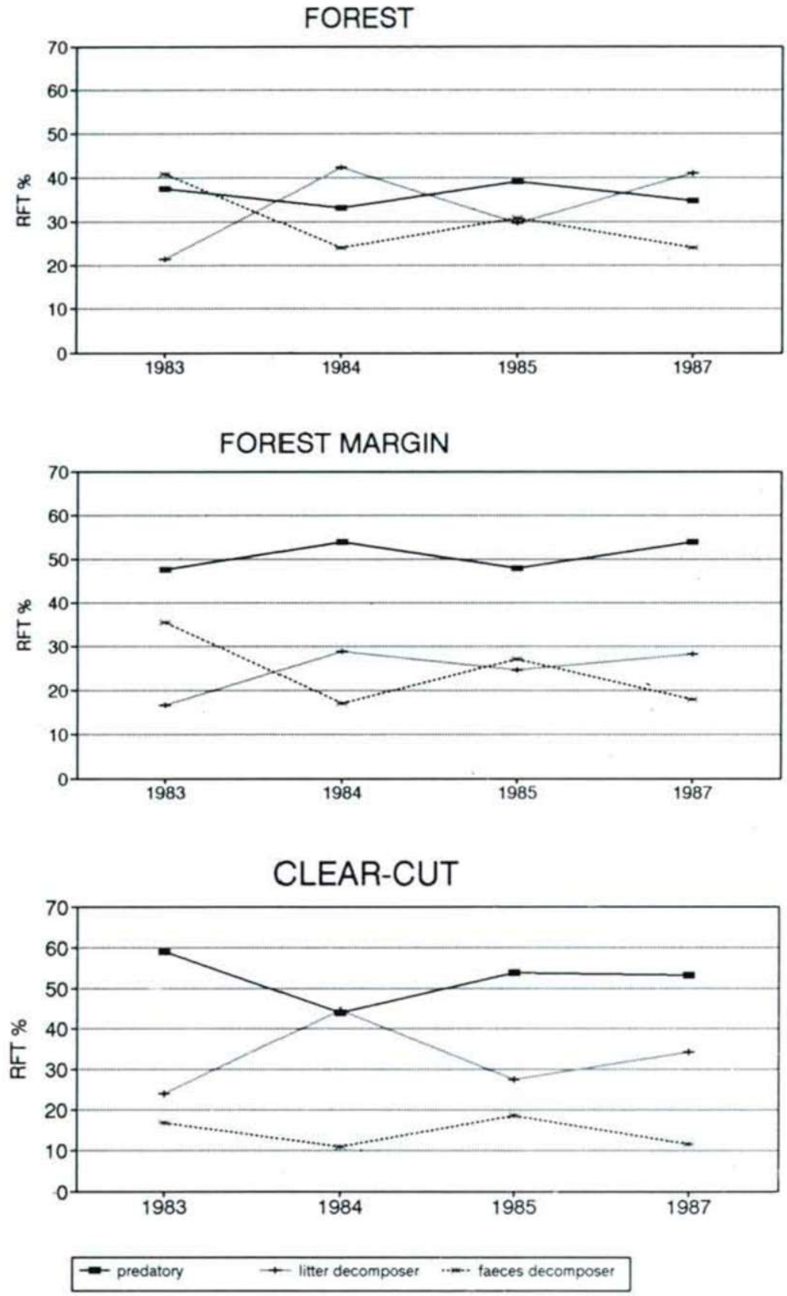

Fig 2. Relative frequency values of predatory groups, litter decomposers in the forest, forest edge and clear-cut area.

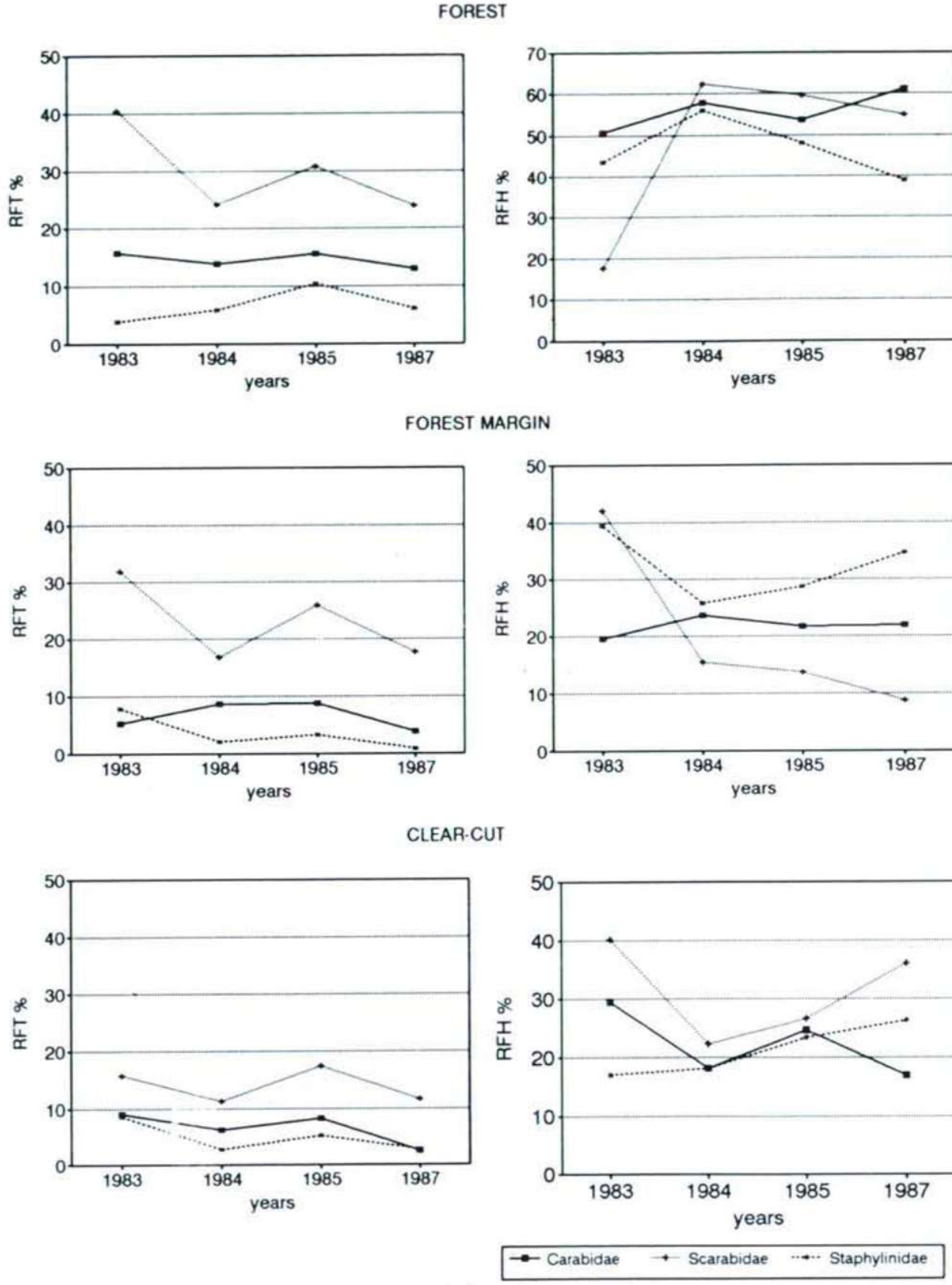

Fig. 3. Relative frequency values of *Carabidae*, *Staphylinidae* and *Scarabidae* taxa compared to the total number of individuals (RFT) and those of each habitat compared to the base (RFH).

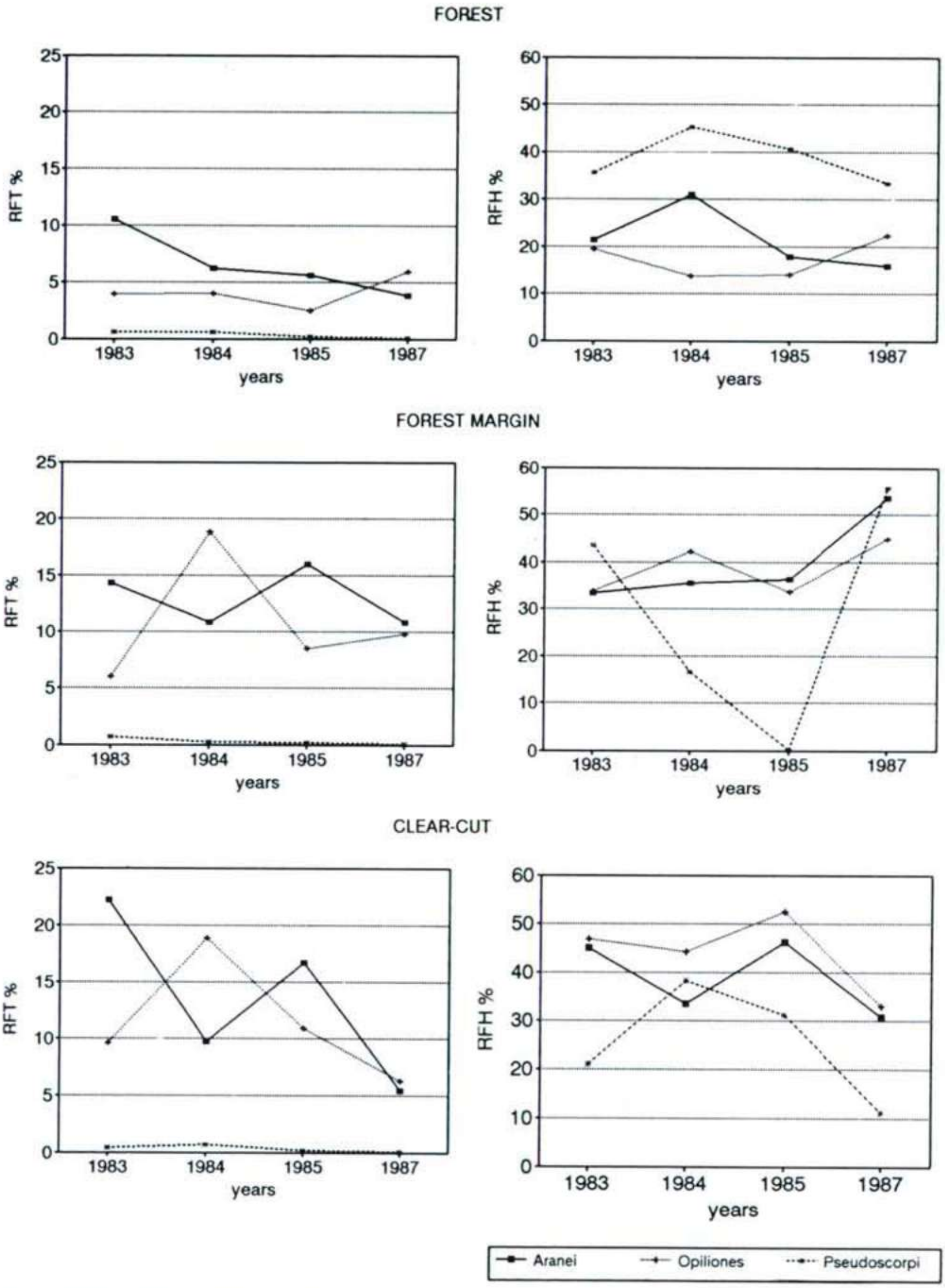

Fig. 4. RFT and RFH values of *Arachnoidea* taxa.

RFT of *Dilopoda*, representative of macrosized litter eaters, hardly exceeds 10-15% during the four years of the study; furthermore this figure comes predominantly from *Juliformia, Glomeridae* and *Polydesmidae*.

Juliformia provide 10% of the total number of individuals at all the three sites, in fairly regular temporal patterns (Fig. 5.).Similar relative frequencies do not imply identical figures of the number of individuals per habitat: the greatest quantities occur in the wood, somewhat less in the clearcut, whilst 20-30% in the intermediate belt. These differences, however, are not considered biologically significant.

The relative frequency of *Glomeridae* is 5-9% in the wood, whereas in the clearcut and the forest margin it is no more than 2-5%. The proportion of total *Glomeridae* counts averages 6-5% in the forest, and 15% in the clearcut and the margin throughout the first three years of the study. However, in the 5th year (the 7th after deforestation) apparent changes began since in the forest decreasing, while outside increasing numbers of individuals were found.

There are very few counts for *Polydesmidae* at every site; consequently, their relative frequency, compared to the whole soil fauna, never exceeds 3%. Interestingly, their abundance peaks in the clearcut in the 3rd and 4th years following disturbance being twice as great as the original score. Later it declines to the level observed in the wood.

The family *Polyxenidae*, represented by a single species, is seen highly infrequent in traps, and even in soil samples it was detected only once in the beechwood in the first year of the study (1983). All these support their presence though do not permit the assessment of their density.

Oniscoidea (terrestrial woodlouse spp.) belongs to the most abundantly represented and most significant litter decomposer taxa. Their relative importance is high with approx. 20%, with yearly fluctuations (Fig. 5.). From the 3rd to the 7th year after deforestation their counts did not remain constant in each habitat either. Their relative abundance (compared to the total soil fauna) is the greatest in the clearcut, followed by the wood and finally the margin; these differences, however, do not imply much significance. The same sequence of habitats can be made according to the distribution of the number of individuals.

Chilopoda were observed to be under-represented by traps; using litter-sooil quadrat blocks considerably larger amounts were caught. Trap captures suggest no significant difference of *Lithobiidae* density between the wood and the clearcut; soil samples, on the contrary, give proof of a higher density in the wood (particularly in the 3rd year after deforestation) than in the clearcut and the intermediate belt. In the following year, however, their numbers increase even in the clearcut, though never approaching those in the wood.

Scendylidae and *Geophylidae*, two other families in question, were detected only in soil samples; their proportions and distributions resemble those of *Lithobiidae* (Table 2. and Fig. 6.).

For *Formicidae* the clear-cut area is highly favourable, since as early as the 3rd year after deforestation greater densities were discerned there than in the margin or the

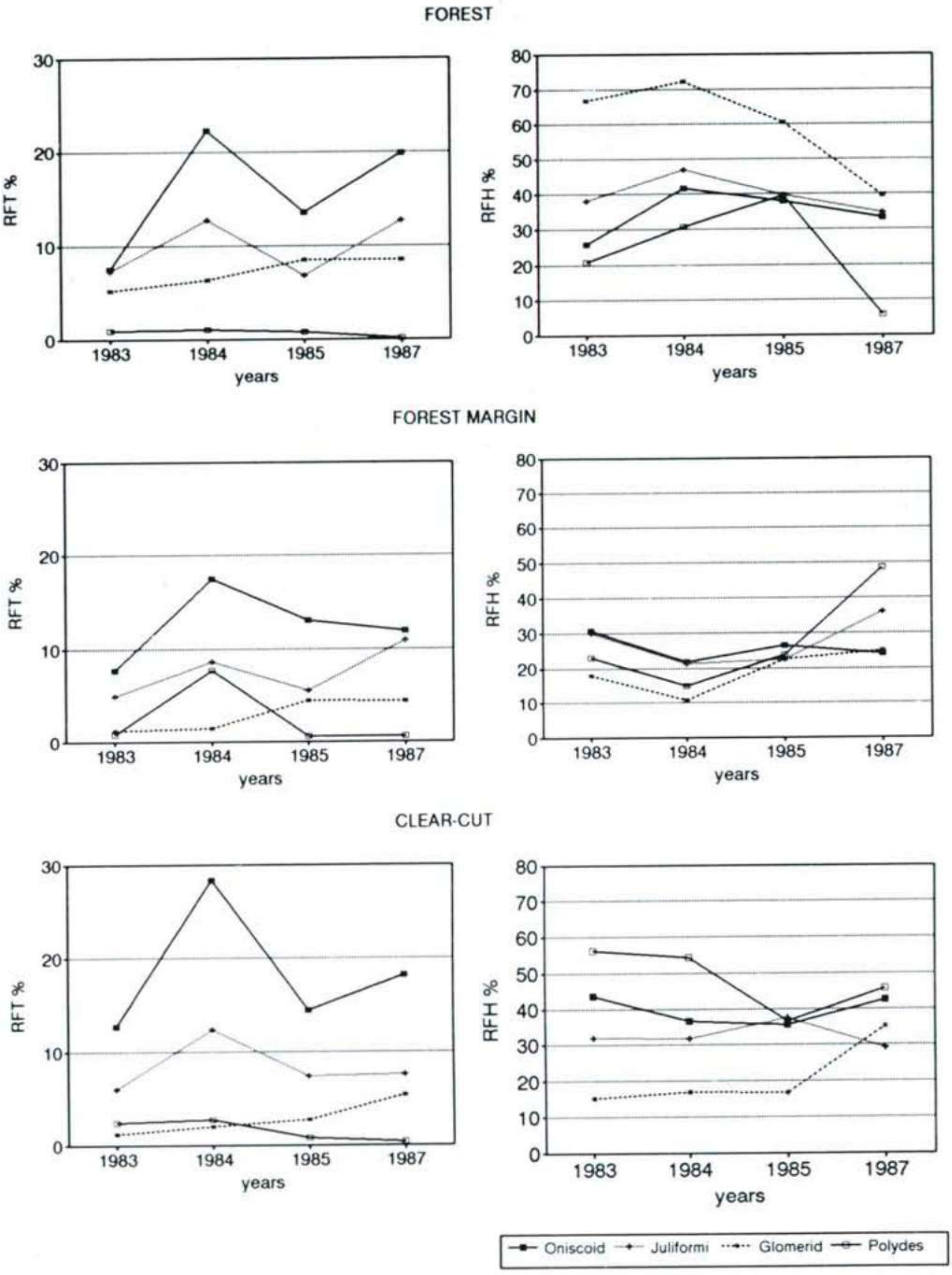

Fig. 5. RFT and RFH values of *Diplopoda* and *Oniscoidea* taxa.

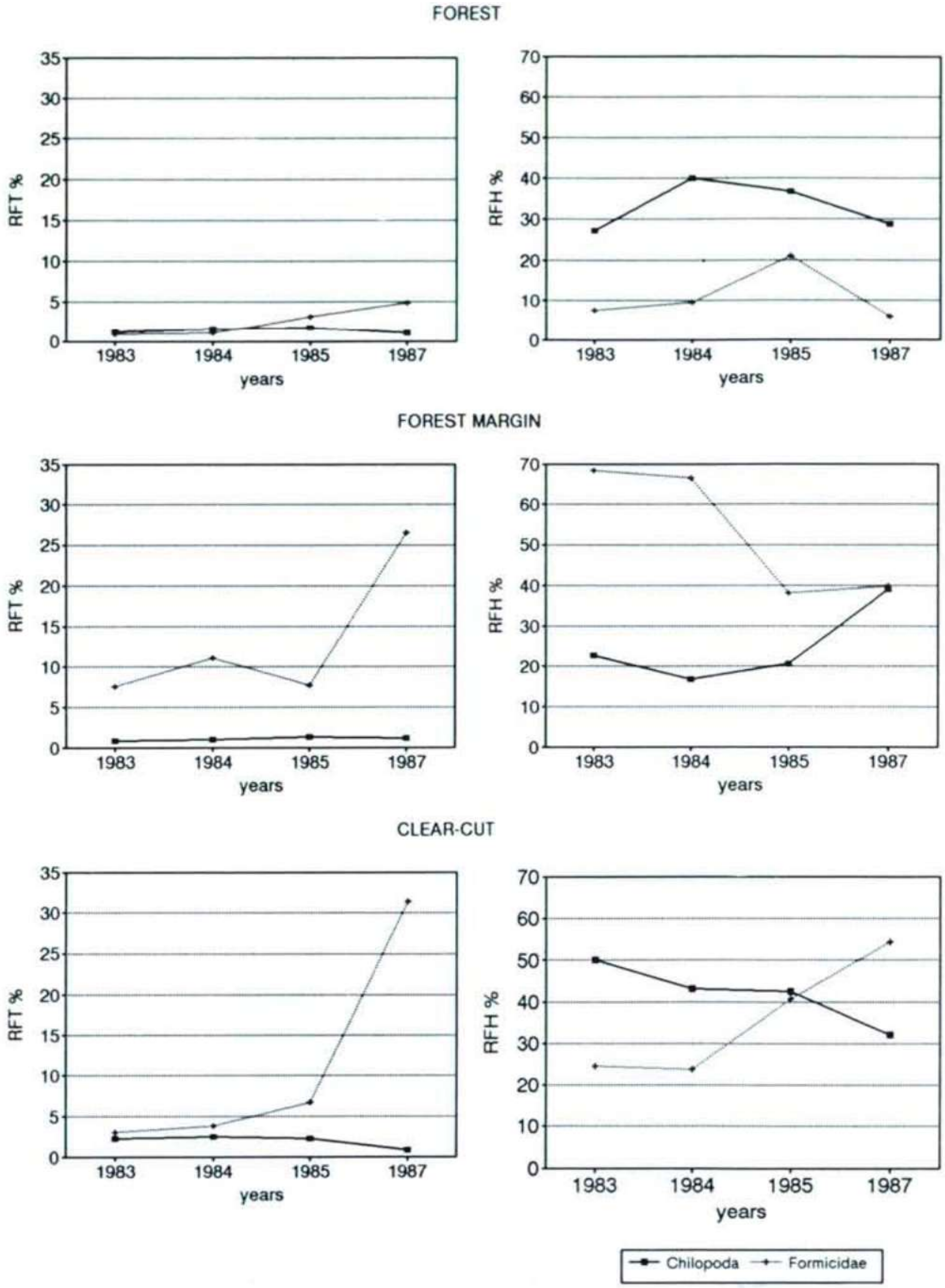

Fig. 6. RFT and RFH values of *Chilopoda* and *Formicidae* taxa.

forest interior (although the former is quantitatively very close to the wood). With time, their numbers rise increasingly, which is also seen in their relative frequenci compared to the whole soil fauna (Fig. 6.).

Other members of the soil arthropod mesofauna, *Symphyla* and *Diplura*, were discovered exclusively in soil samples. The former taxon was found, from the 3rd year after disturbance, in slightly larger quantities in the clearcut than in the other habitats. There was no record of *Diplura* in the clearcut in 1983, but displayed corresponding densities in the three sites the next year.

Table 1. Average number of individuals calculated for one trap per year

count/trap	83.	84.	85.	87.	83.	84.	85.	87.	83.	84.	85.	87.
	clearcut				margin				beech forest			
Carabidae	31	24	40	9	20	32	34	12	52	77	86	33
Scarabidae	53	43	83	41	122	61	102	54	135	132	170	61
Staphylinidae	29	11	25	10	31	8	13	3	13	32	57	16
Aranei	75	37	80	19	55	40	63	33	35	34	31	10
Opiliones	32	72	53	22	23	69	34	30	13	22	14	15
Pseudoscorpionidae	1	3	1	1	3	1	1	1	2	3	1	1
Chilopoda	8	10	11	3	3	4	5	4	4	9	9	3
Juliformia	20	47	36	37	19	32	21	33	24	70	38	32
Glomeridae	4	8	13	19	5	5	18	14	18	35	47	21
Polydesmidae	8	10	4	2	3	3	3	2	3	6	4	1
Isopoda	43	108	70	64	30	64	51	36	8	22	14	20
Formicidae	10	15	33	110	29	41	30	61	3	6	17	12

Table 2. Distribution of taxa examined in soil samples per m^2 during 1983, 1984, 1985 and 1987.

	1983.	1984.	1983.	1984.	1983.	1984.
	beech forest		margin		clearcut	
Pseudoscorpionidae	29	3	3	-	0	19
Juliformia	105	54	56	-	19	45
Glomeridae	4	6	0	-	0	0
Polydesmidae	1	6	6	-	0	13
Polyxenidae	6	0	0	-	0	0
Scendylidae	41	29	16	-	2	48
Geophylidae	28	6	0	-	0	15
Symphyla	25	22	51	-	34	35
Diplura	29	35	21	-	0	29

Discussion

The *Carabidae* and *Staphylinidae* faunas of forested and clear-cut areas were studied by SUSTEK (1984) and KABACIK (1957). The former found lower abundance of carabid and staphylinid beetles in a clearcut than in the adjoining wood. KABACIK, studying *Carabus arvensis*, drew attention to migration between forets and clearcut. CYKOWSKY (1975), comparing forest and meadow, concluded that grasslands maintain less abundant carabid faunas than forests do, although transitional zones are more similar to forested areas in character and have more carabids. KLEINERT (1977) came to the same conclusion investigating *Staphylinidae*, but in *Carabidae* he found larger abundance on a pasture.

The comparison of the beechwood and the clearcut in my studies at Rejtek also suggests higher relative frequencies of *Carabidae* and *Staphylinidae* in the forest. Consequently, the distribution of the number of individuals among the three localities shows that it is the wood that maintains 50-60% of the entire Carabidae and *Staphylinidae* populations (see Fig. 3.), whereas in the margin and the clearcut only 20% occurs, respectively. The species spectrum, when explored, would no doubt reveal that the species composition of the habitats differs as well as alters, also indicated by the decrease of *Staphylinidae* numbers in the 3rd and 4th year after deforestation, which is succeeded by an accelerating increase later. Presumably, r-strategist species with broader ecologic tolerance spectra are gradually replaced by K-strategists, also demonstrated by WINTER et al. (1983). Larger quantities of *Carabidae* and *Staphylinidae* in the wood certainly result from limited dispersion capabilities imposed by more specialized ecologies rather than food as aresource.

Corresponding surveys on the soil fauna on the "Rejtek" research area were accomplished by SZABÓ (1985) in 1985 and IZSVÁK (1984) in 1983, contrasting beechwood with clearcut. Their results support my observations on *Carabidae* and *Staphylinidae*. Besides the above two taxa, however, they studied Scarabids and big litter decomposers as well.

SZABÓ (1985) found that the proporion of *Scarabidae* relative to the whole soil fauna increased in the clearcut-forest direction five years after deforestation. My results do agree with this, pointing out the wood to support greater abundance of *Scarabidae* than the clearcut and the forest skirt do, namely in each year of the study. It must be noticed, however, that in clearcuts frequently visited by game far denser faeces cover is present than in the forest.

Probably it is the microclimate and exposition of the clearcut that have adverse effects on the expansion of scarabids.

The occurrence patterns of *Oniscoidea* (a group belonging to Isopoda) on the clear-cut area deserve special attention. Their frequency was found higher on the deforested area, albeit they are known to be controlled considerably by Ca^{2+}, pH and humidity (DUNGER, 1983). According to their ecological demands and tolerances, the single families are very diverse as well. What can then account for their slightly greater abundance in the clearcut despite its extreme microclimate? As a plausible explanation, the decreasing pH (acidification) of soil can be considered, described by BODNÁR (1989) and HOLES (1985).

After deforestation, intensive microbial activity leads to higher rates of mineralization of organic matter in soil (SEASTEDT and CROSSLEY, 1981; ABBOTT and CROSSLEY, 1982), which offer *Oniscoidea* favourable environments. As secondary succession proceeds the area becomes increasingly reforested moderating extreme microclimatic conditions. This may explain the similar frequencies and numbers of individuals in the forest and the clearcut in the 7th year after clear-felling.

SZABÓ and IZSVÁK consider clear-cutting an ineffective factor in controlling the abundance of *Diplopoda*. In their studies *Diplopoda* was treated as a homogeneous group; in my investigations, however, the families *Juliformia, Glomeridae* and *Polydesmidae* were handled as single units, leading to somewhat different results.

Although the total counts of *Juliformia* are unevenly distributed among the three habitats (see Fig. 5.), relative frequency values appear uniform in agreement with the above authors.

Approximately 60-70% of all *Glomeridae* records occurred in the forest, even in the 5th year following deforestation; the rest is divided equally between the clearcut and the forest edge. After this year, howqever, the number of individuals rises notably both in the clearcut and the forest margin, also modifying the relative frequencies (Fig. 5.).

The family *Polydesmidae* is present with small numbers of specimens, showing a slightly decreasing trend in the clearcut. Its relative frequency is constant throughout the thre localities.

Among *Diplopoda, Juliformia* appears the least sensitive of all to changes in microclimate (mainly humidity); or rather, they have evolved an active defence mechanism, i.e. the ability of burrowing to help them survivie extreme microclimates by staying deeper in the soil (DUNGER, 1983). The lack of this capacity necessitates glomerids to exist in litter. Since the soil of the clearcut is rather shallow and full of stones, it offers refuge to the even more hygrophylous *Polydesmidae* spp., which are present there as well as inside the wood, although with extremely low abundances.

The only attending member of *Polyxenidae, P. lagurus* occurs sporadically in soil samples from the forest (Table 2.), but is missing from the clearcut.. Its thin cuticula makes it the most vulnerable of all diplopods and accounts for its sparse occurrence.

WINTER (1987) and SCHAEFER (1988) studied the soil fauna of a burnt-down pine forest from the very first growing season after fire. Winter found that the area was colonized exceptionally fast by *Carabidae*, resulting in great abundance and diversity of r-strategists, which were replaced by K-strategists 2-3 years later.

In *Aranei* and *Opiliones* colonization, basically by immigration, is time-consuming, requiring 2-3 years for *Aranei* to reach the original species number and even more for *Opiliones*. However, species composition will not be the same. Among spiders, surface hunters must be considered in the first place. The effect of disturbance by clear-cutting are less drastic than those after downburning, thus in the third year following clear-felling large abundance characterized the area being twice the original value of the wood. Abounding herbaceous vegetation offers plenty of prey for both carnivorous groups. According to relative frequencies they seem to be antagonists in the clearcut, while in the forest *Opiliones* become out-competed.

In a clearcut made in a mixed pine-deciduous stand, changes in the soil fauna were surveyed by HUHTA (1976), focusing mainly on *Aranei*. Still in the second year after deforestation he found less abundant captures in the clearcut than in the control wood. Moreover, the forest score was not approached until the 5th year. It must be noted,however, that our beechwoods have extremely sparse undersorey vegetation, whereas the above mixed pine-deciduous forests posses more substantial covers. HUHTA showed that *Chilopoda, Thysanura* and *Formicidae* were also less abundant in the second year, and it was just *Collembola* that had more counts in the clearcut at that time. In chilopods, similar frequencies between the habitats were found five years after disturbance.

My results show that the density of my object chilopod families (*Lithobiidae, Geophylidae, Scendylidae*), according to soil samples, was ten times smaller in the clearcut than in the wood in the 3rd year after deforestation. At the same time, the number of individuals in traps was slightly greater in theclearcut than in the forest. In the next growing season the number of chilopods increased according to both sampling procedures. *Chilopoda* comprises organisms awfully sensitive to changes in environmental factors such as humidity and temperature. Owing to their hidden life history there is some uncertainty in evaluating the confidence of sampling. Exploring species composition will enable a more precise description of their distribution.

According to Huhta (1976) the frequency of *Formicidae* is increased remarkably in the clearcut in 5-8 years and stays high indefinitely. The number of ants in covered traps does not reflect the accurate population densities but provides rough estimates. However, these data allow an approximate picture of *Formicidae* densities for temporal comparisons among the habitats. Obviously, their relative abundance increases in the clearcut and is respectably high in the forest margin, whereas in the wood it remains low albeit increasing. Their overwhelming emigration activity and expansion result from the abundance of food in the first place.

Symphyla and *Diplura* provide a scarce group of the soil fauna, with strange and hidden life histories. In literature they are not treated as distinct categories but as "miscellaneous". These creatures with thin cuticula, sensitive to dehydration, are able to survive in the clearcut finding refuge in soil cavities and cracks as well as under stones; the most favourable conditions, however, were found to be provided by the forest edge.

According to the analysis of these components of the soil mesofauna we can conclude, regarding the various feeding strategies, that the proportion of carnvores increased after clear-cutting, the importance of faeces decomposers decreased, while that of litter decomposers remained nearly unaffected. In the forest margin, the frequency of carnivores is close to that in the clearcut; litter decomposers are seen the least abundant here, whereas faeces decomposers display an intermediate position between forest and clearcut.

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